Analysis of SME ship repair yard capacity in building new ships

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ABSTRACT: The objective of this work is to analyse the existing capacities of a small sized ship repair yard in building new ships, accounting for the existing constraints raised from the implemented ship repair technology, facilities, equipment and human resources. The output of the study is to identify what kinds of measures are needed to upgrade the already implemented technology and infrastructure so that the SME ship repair yard can build new ships. Two optional solutions for building new ships are proposed, including some measures in the enhancement of the equipment and shipyard technological processes. The major conclusion is that the analysed SME shipyard has sufficient workshop space and floating dock capacity that may be employed in building new ships of different type with a dead weight up to 7,000 tons.

1 INTRODUCTION

The small and medium sized enterprises (SME) are the backbone of the industry and the governments are taking care of their development. The European shipbuilding and ship repair industry is made up of around 300 yards and more than 80% are considered to be 'small to medium' enterprises, SME (LeaderSHIP2020, 2013). On other side, the European marine equipment manufacturing and industry (propulsion, cargo handling, communication, automation, integrated systems, etc.) is made up of around 7,500 companies, the clear majority is also considered SMEs.

According to Unit_E.4. (2009), 99 percent of the European SMEs generate about 58 percent of the EU's turnover, employing two thirds of the total private employment and in the last 5 years, 80 percent of the new jobs were created by them.

However, Parc and Normand (2016) claimed that more effective policies for enhancing the competitiveness of European shipbuilders is necessary by taking a holistic approach to solve core problems. The reason for that is the simultaneous implementation of two competitiveness strategies i.e. 1) cost leadership and 2) differentiation. With respect to the first strategy, the companies try to ensure competitive advantage over costs and according to the second one it is seeking to be unique in its industry. Considering the advantages of the European shipbuilding industry, attention should be paid to constructing expensive and complex vessels that yield a high added-value.

Lee (2013) analysed the efficiency, productivity, growth, and stability of Korean SMS shipyards and suggested some directions for improvements. One alternative for SMS shipyards is to switch to the marine equipment industry or to maintenance and repair of ships. Third alternative is the ship breaking though as a labour-intensive industry it is developing in China, India, Bangladesh, and Pakistan. Fourth direction suggested is establishing the subcontract structure as a value chain among large shipyards and SMEs. Finally, the possible solution is building clusters with governmental support in many ways.

The Maritime Administration, Department of Transportation (USA) has provided Small Shipyard Grant Program, with $9,800,000 available for grants for capital and related improvements to qualified shipyard facilities that will be effective in fostering efficiency, competitive operations, and ship construction, repair, and reconfiguration. (https: //www.marad. dot.gov).

There are an increasing number of scientific publications devoted to the problems of a small shipyard. Song et al. (2009) presented a simulation-based support system for a ship production management that can be applied in SMEs for different processes. The simulation includes the layout optimization, load balancing, work stage planning, block logistics and material management.

Typically, the basic planning and initial design in SMEs are done by design agents, outside the shipyards, and outfitting and detailed designs for construction are done in the shipyards. Shin et al. (2012) proposed a prototype of ship basic planning system for SME based on the internet technology and concurrent engineering concept. The used internet environment enables remote design and information exchange between shipyards and design agents.

The use of modern CAD tools is of particular importance for the competitiveness of SMEs. Paine et al. (2013) shared the experience gained from implementation many commercially available design software packages with vessel models for automatic generation of bill of materials (BOM) combining with an in house developed material requirements planning (MRP) system. The basis of the concept is to develop a low budget integrated design and production system suitable for a small shipyard.

In the last decade, various “Design for X” methods have been developed. The goal of “design for production“ is reducing production cost without sacrificing the design performance or product quality (Misra, 2016). Some of considered aspects include:

- Simplicity in design: minimum number of parts; reduction in part variability; reduction in welding joint length; standardization of parts; integration of structure and outfit etc.;
- Design based on shipyard facilities: limits on ship dimensions; maximum weight and size of blocks; maximum size of panels - panel line turning and rotating capabilities; maximum berth loading; launching limitations;
- Other production considerations: simplified hull forms; avoidance of double curvature and large single curvature; developable surfaces; constant hold or tank length, constant hatch size, etc.

The goal of the presented study is to analyse the existing capacities of a small sized ship repair yard in building new ships, accounting for the existing constraints. This analysis is a part of the Shiplys project (Bharadwaj et al., 2017) Scenario 2 related to the development of a software tool for a conceptual ship design accounting for the risk-based life cycle assessment (Garbatov et al., 2017b).

The output of the present study is to identify what kinds of measures are needed to upgrade the already implemented technology and infrastructure so that the SME ship repair yard can build new ships.

2 CURRENT SHIPYARD BULDING CAPACITY

The existing production areas and facilities, implemented technology and human resources of the ship repair yard allow partial and class repairs of small and middle-tonnage ships of different types. Ship-yard’s building berth area of analysed SME ship re-pair yard consists of four ship building berths,
equipped with one floating dock, № 2, with a floating system for vessel lifting and shifting. The floating dock can accommodate vessels with length over-all/breadth of 136/16 meters with a maximum launching weight of 1,800 tons. These restrictions limit the build or repair of the vessel deadweight of about 6,000 to 7,000 tons.

The existing larger floating dock, №1, can accommodate vessels with length overall/breadth of 155/22.8 meters and with a maximum launching weight of 7,500 tons, which corresponds to ships with a maximum deadweight of about 20,000 tons.

The existing production hall was built around the launching complex (Figure 1, position 1). The hall is with the following dimensions – a total length of 192 meters (8 sections, each of 24 meters), a width of 96 meters and a length of 10.8 meters. The hall has not been equipped yet. Two of the sections have specialized areas for the processing of constructions, intended to be used for ship hull repairs.

Several conclusions may be derived with respect to the fact that currently, the shipyard does not have capacity of building new ships due to the lack of ad-equate facilities and equipment, and to correct this deficiency in the case of building new vessels the followings need to be fulfilled:

- to complete the production hall (Figure 1, position 1) and to be equipped with the appropriate machines, crane and other equipment, required for the processing of plates, profiles and production of welded joints and sections;
- a pipe preparation shop has to be set up in the production hall;
- in the eastern part of the production hall must be established a site for the pre-slipway assembly, that may be equipped with appropriate production systems, including gantry cranes with a lifting capacity of 30 to 40 tons;
- the new ship building may also be performed employing the existing building berth in the eastern part of the launching complex. A new building berth may also be established there. The building berths are to be equipped with cranes with a lifting capacity not less than those on the site for a pre-slipway fitting;
- the ship superstructure assembly site has to be established in the vicinity of the Berth Wall II.

3 SHIPBUILDING TECHNOLOGY

Assessing the currently existing capacity and if the above described shipyard retrofitting is implemented, the yard will be able to perform new shipbuilding along with its ship repair program. To construct new ships, two options are possible, which can be defined as a function of the location of the building berth:

- Option 1 – the hull assembly may be performed on the building berth of the Floating dock № 1;
- Option 2 – the hull assembly may be performed on the building berth, which is a part of the launching complex.

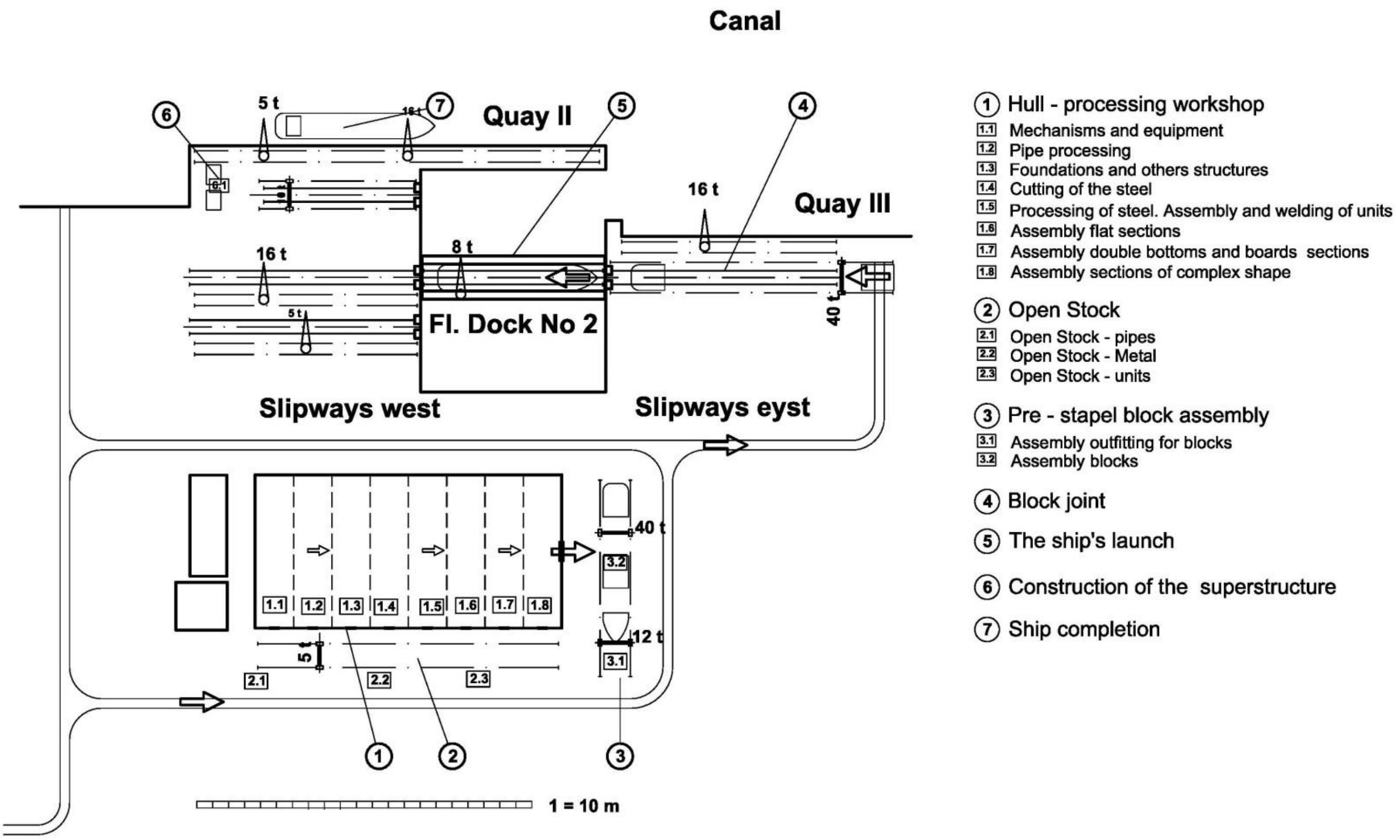

Figure 1 Shipyard facilities

In the case of Option 1, the Floating dock № 1 has to be equipped with an appropriate crane with a lifting capacity not less than 50 tons, otherwise the existing crane of 5 tons will limit the assembly capacity of the building berth.

Option 2 considers the maximum load carrying capacity of the Floating dock №2, which is about 1,800 tons. In the case of relatively large ships, the building berth may assemble the ship hull, ship systems and equipment, main engine and propulsion system and if it is possible may include some large-sized machinery and equipment in the engine room. The ship construction afloat includes the assembly of the superstructure and all remaining completion works.

In the following tables, the technological process for a new ship building in the shipyard's building berth complex is described. The general layout of the production process and associated production areas of a hull construction is shown in Figure 1. The remaining technological shipyard equipment will ensure the implementation of the mechanical, metal, electrical and other works. The mounting and testing of the equipment and gears is carried out by the manufacturers.

Currently, the shipbuilding process may be performed following the next stages:

- the zero processing of the base material: plates and rolled profiles may be performed in the existing facilities or may be subcontracted to the existing neighbour's shipyards (Table 1/1).
- cleaning and cutting of plates and rolled profiles, including bending of rolled profiles may be performed in the hull workshop as can be seen in Figure 1, position 1, where a specialized area will be established. Table 1/2 shows the equipment needed to perform cleaning, cutting and bending of plates and profiles.
- the process of fabrication of sections – plane and curved will be performed in the Hull workshop as can be seen in Figure 1, position 1, where a specialized area in the section 1.5 will be established. Table 1/3 shows the required equipment.

3.1 *Assembly and welding of sections*

This stage of the production covers the following processes:

- the assembly and welding of plane sections – forming plates and fitting the frames and reinforcements in the case of flat sections. This pro-cess will take place in the Hull workshop; see position 1 in Figure 1, where a specialized area in the Section 1.6 will be established. Table 2/1 shows the required equipment.
- the assembly and welding of the double bottom, side shells and curved sections will be performed in the hull workshop, see the position 1 in Figure 1, where a specialized area in the section 1.7 will be established. Table 2/2 shows the required equipment.
- the assembly and welding of the 3-D sections

will be performed in the hull workshop as can be seen from the position 1 in Figure 1, where a specialized area in the section 1.8 will be established. Table 2/3 shows the required equipment.

Table 1. Stages of the technological process

	Processing	Equipment	Characteristics
1.1	Zero processing of plates and profiles	Subcontracted service	
1.2	Cleaning, cutting and bending of plates and profiles	ZINSER Gas Cutting Machine Plasma cutting machine Vertical hydraulic press Profile bending hydraulic press Stacking crane Stacking crane	4 x 12 m 2,2 x 12 m 250 t; 800 mm 8 t; jib with electrical magnets 5 t;
1.3	Fabrication of welded joints, assemblies and sections	Assembly pallets Three rolled bending machines Hydraulic profile bending machine Mechanical cutting machine Stand for T-shaped profile Stacking crane Stacking crane	S= 20 mm; L= 800 mm S=16mm; L = 2,5 m 8 t; 5 t;

3.2 *Pre-slipway assembly*

In the eastern part of the production hall will be established a specific site for a pre-slipway assembly, as can be seen in the position 3 in Figure 1. The required equipment is shown in Table 3.

At this production stage, the following processes will be carried out:

- outfitting of the constructions;
- consolidation of volumetric sections – the constructed sections are consolidated in blocks and (or) conglomerations in the pre-slipway assembly area.

3.3 *Assembly on building berth*

The 3-D assembled structures, mechanisms and equipment will be mounted using the building berth, which has a capacity of the admissible launching weight of 1,800 tons.

Table 2 Assembly and welding of sections

	Processing	Equipment	Characteristics
1	Assembly and welding of flat sections - Section 1.6	Welding portal for sheets Welding portal for sheets Hydraulic press for Direction I frames Stacking crane Stacking crane	NA - 5S 12.5 t; 12.5 t;
2	Assembly and welding of double bottom, boards. Outfitting - Section 1.7	Tooling for French curve templates Stacking crane Stacking crane	12.5 t; 12.5 t;
3	Assembly and welding of curved and volumetric sections. Outfitting - Section 1.8	Tooling for French curve templates Telescopic stand for French curve template Stacking crane Stacking crane	12.5 t; 12,5 t;

Table 3 Pre-slipway assembly

	Process	Equipment	Characteristics
1	Outfitting	Gantry crane	12.5 t;
2	Consolidation in blocks and conglomerations	Gantry crane Gantry crane	12.5 t; 40.0 t;
3	Consolidation in volumetric sections	Gantry crane Gantry crane	12.5 t; 40.0 t;

Table 4 Assembly on a building berth

	Processes	Equipment	Characteristics
1	Positioning of the building berth support	Slipway cars	Slipway system
2	Positioning and aligning of blocks	Gantry crane, Bridge crane	40.0 t; 16.0 t;
3	Hull welding		
4	Main engine mounting	Floating (mobile) crane	100.0 t;
5	Gears and installations fitting	Bridge crane	16.0 t;
6	Hull testing before launch.		
7	Painting		
8	Positioning on a dock and launching afloat	Floating dock №2	Slipway system

The ship assembly will be performed on the eastern building berth. The required equipment is shown in Table 4. At this production stage, the following processes should be carried out:

- placing/positioning of the building berth support – slipway cars;
- positioning and aligning of blocks - ship hull blocks are assembled consecutively;
- hull blocks are welded;
- mounting of the main engine;
- fitting of gears and installations;
- hull testing before launching;
- painting;
- positioning on a dock and launching afloat.

3.4 *Completion afloat, testing and trials*

The ship's completion is carried out on the completion berth as can be seen from the position 7 in Figure 1. The required equipment is listed in Table 5. At this production stage, the following processes will be carried out:

- fitting of machinery and systems.
- mounting of the superstructure – consolidation of superstructure constructions is carried out on a specialized site, which is located at the position 6 in Figure 1.
- mounting of deck constructions, machinery, gears, systems, electrical, navigational and other equipment;
- superstructure outfitting;
- completion works;
- tests on a mooring station and sea trials.

Table 5 Completion afloat, testing and trials

	Processes	Equipment	Characteristics
1	Fitting of machinery and systems in the main engine room	Bridge crane	16 t.
2	Superstructure mounting	Floating (mobile) crane	100 t.
3	Mounting of deck constructions, machinery, gears	Bridge crane	16 t.
4	Superstructure outfitting	Bridge crane	16 t.
5	Completion works.	Bridge crane	16 t.
6	Tests on a mooring post		
7	Sea trials		
8	Delivery		

3.5 *Transportation*

The transportation of the sections made in the construction workshop to the assembly site and from there to the building berth will be done by a transport platform with a carrying capacity of over 50 tons. In-house transport between the workshops consists of non-self-propelled rail trolleys exist.

3.6 *Delivery of resources and equipment, warehousing and depot*

The plates and profiles will be transported after the "zero" treatment of the material by vehicles or by sea barges. Near the hull workshop (Figure 1, position 2) is to be set up an open warehouse for base materials and intermediate assembly of units.

4 SHIP DESIGN FOR BUILDING IN SME SHIP REPAIR SHIPYARD

As multi-purpose vessel's capacity increases, the efficiency improves, and the objective here is to assess the impact of the restrictive production conditions of an SME ship repair shipyard.

In this case, the restrictions are determined by the capacity of the launching complex of the yard, which has the following limitations:

- maximum docking capacity – 1,800 t. This condition defines the maximum weight of the ship upon the launching – the lightweight (LW_1), which includes ship hull and all units that need to be mounted before the ship launching in the water;
- maximum dock dimensions that allow a ship to be built with a length not greater than 135.8 meters and a breadth not greater than 16 meters;
- the depth of the fairway determines the draft of the ship to be no more than 8 meters.

Based on the numerical analysis, employing concept design software tool "Expert” (Damyanliev & Nikolov, 2002), the investment costs, CAPEX is adopted as a criterion for evaluation of the design solutions. The software tool "Expert” has been also recently employed in defining design solutions subjected to different constraints by Damyanliev et al. (2017), Garbatov et al. (2017a).

Table 6 shows the optimum main dimensions for ships with deadweight from 5,000 to 10,000 t. Here the main dimensions do not have any restrictions.

Table 7 shows the optimum main dimensions for ships with deadweight from 5,000 to 8,000 t, accounting for a constraint arising from the vessel’s breadth of 16 m. These results are shown in Figure 2, Figure 3 and Figure 4.

All vessel designs are shown in Table 6 have a breadth of more than 16 meters. To fulfil the sets of deadweight accounting for the constraint of the breadth, the length is increased. Because of that, the draft is reduced, which can be explained by the condition of reaching the required minimum of the stability.

Based on the chosen optimization criterion, CAPEX, the designed ships without breadth limitations are relatively short with low ratios of L/B and L/D.

Table 6 Ship design solutions for different DW

DW, t	5,000	6,000	7,000	8,000	9,000	10,000
L, m	86.79	93.21	96.71	99.98	109.81	115.21
B, m	16.17	16,.7	18.60	19.23	19.77	19.75
d, m	7.18	7.33	7.98	8.53	7.99	8.34
D, m	8.90	9.32	10.06	10.81	10.44	11.03
L/B	5.37	5,.2	5.20	5.20	5.56	5.83
B/d	2.25	2.30	2.33	2.26	2.47	2.37
L/D	9..6	10.00	9.61	9.25	10.52	10.45
Cb	0.685	0.676	0.67	0.669	0.714	0.721

The lightweight, LW_1, (as opposed to LW) includes the weight of the main hull, without 20% of the deck plating, part of the gears, including the steering gear, main engine and propulsion system.

Table 7 Ship design solutions for different DW, B=16 m

DW, t	5,000	6,000	7,000	8,000
L, m	88,63	106.60	120.62	135.06
B, m	16.00	16.00	16.00	16.00
d, m	7.08	6.88	6.67	6.57
D, m	8.81	8.93	9.03	9.17
L/B	5.54	6.66	7.54	8.44
B/d	2.26	2.33	2.40	2.44
L/D	10.06	11.93	13.36	14.73
Cb	0.69	0.721	0.772	0.812

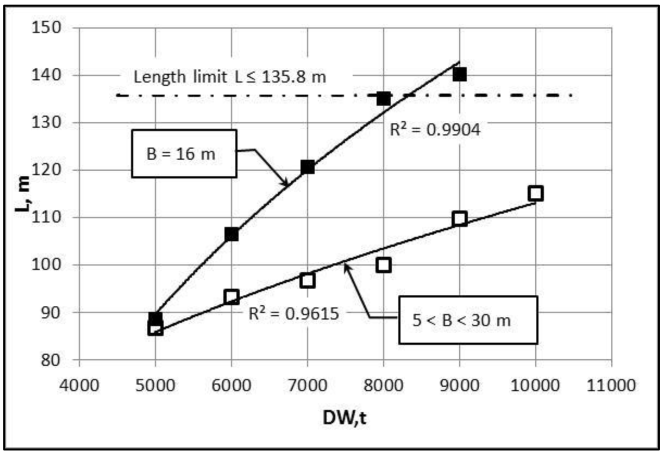

Figure 2 Main dimensions as a function of DW (L<135.8 m)

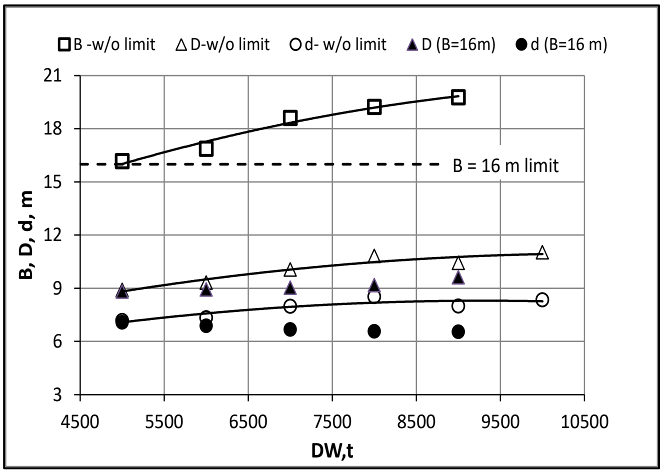

Figure 3 Main dimensions B, D, d as a function, of DW

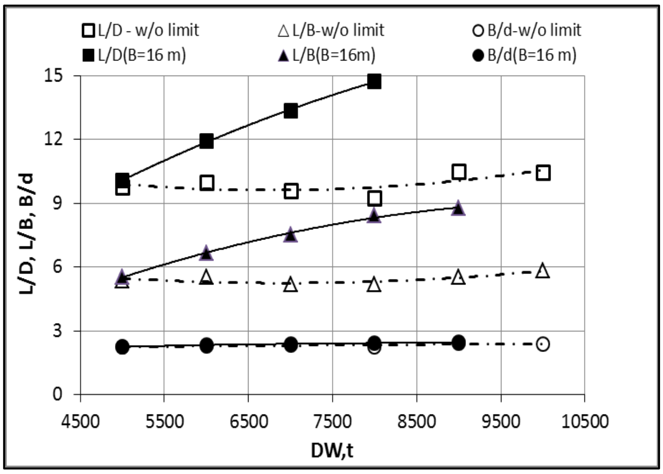

Figure 4 Main ratios as a function of DW

The weight characteristic of the vessels, LW_1 is presented as a function of the deadweight, DW in Table 3 and 4.

Table 8 LW as a function of DW, B=16 m

DW, t	5,000	6,000	7,000	8,000	9,000	10,000
LW_1, t	1,127	1,438	1,745	1,835	2,030	2,331
LW, t	2,079	2,542	2,997	3,243	3,400	3,445

Table 9 LW as a function of DW, without restriction

DW, t	5,000	6,000	7,000	8,000
LW_1, m	1,153	1,566	1,948	2,429
LW, m	2,104	2,678	3,550	3,831

These are the systems without the ship cannot be launched into the water. In terms of the maximum docking capacity, the maximum weight of the ship will be around 6,700 t with vessels of a limited breadth of 16 m (see Table 8) and about 7,500 t for those without a restriction (see Table 8Table 9).

Figure 5 shows how LW_1 changes as a function of B and DW and Figure 6 presents, in a relative form, the variation of CAPEX, chosen as a function to be minimized. The imposed limitation on the breadth of the ship leads to a significant increase in the relative capital with a deadweight of the designed ships over 6,000 t. The optimal vessel with a limited breadth up to 16 meters is with deadweight of 5,500 t, where after CAPEX increases essentially.

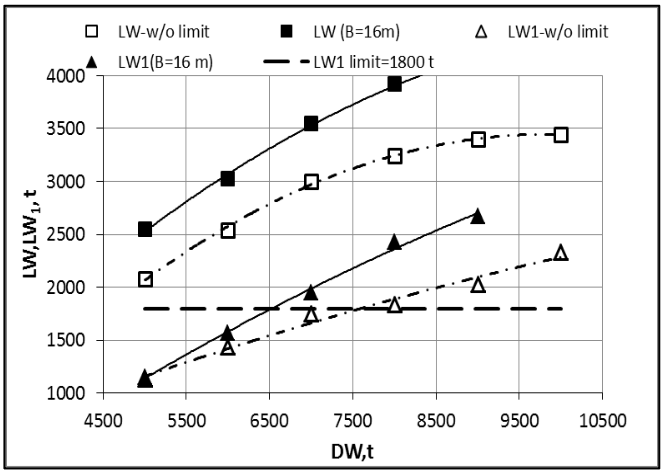

Figure 5 Light weight LW and LW_1 as a function of DW

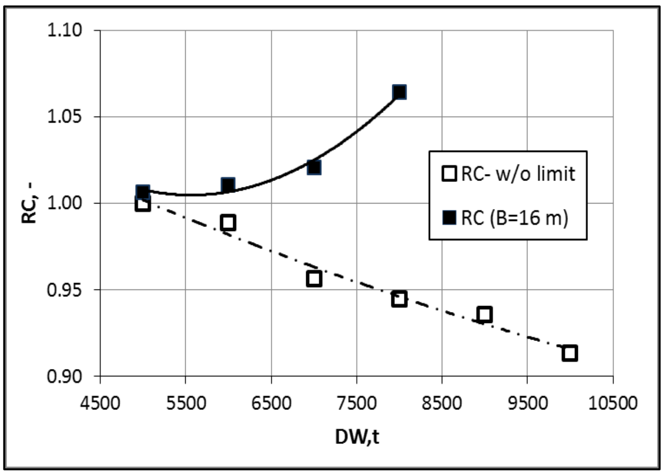

Figure 6 Relative CAPEX (RC) as a function of DW, t and influence of B limit.

5 CONCLUSIONS

The objective of the present analysis was to identify the existing and needed capacity to build new ships in the condition of a small sized ship repair yard. The conclusion derived is that the new building of ships of different types with deadweight up to 7,000 t is possible to be carried out along with the existing repair capacity in the analysed SME ship repair yard. Considering the shipyard's resources and its technological equipment, it is possible to build a new MPS up to 7,000 t in a building cycle of eight months.

From the results shown, the following conclusions may be derived:

– a determining factor in defining the main characteristics of the ship is the width of the dock;
– the dock length affects only vessels with a limited breadth and with deadweight of above 8,000 t;
– the permissible docking capacity is a limitation for vessels with an unlimited and limited breadth, with a deadweight of 7,200 t and 6,800 t, respectively.

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